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1 April 1962 - 31 March 1963

RESEARCH ON RELATIONS BETWEEN COMETARY, SOLAR AND UPPER ATMOSPHERIC PROCESSES

P. SWINGS
and collaborators

UNIVERSITY OF LIEGE
DEPARTMENT OF ASTROPHYSICS

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TABLE OF CONTENTS.

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ABSTRACT.

Laboratory work has been carried on time resolution of spectra in the vacuum ultraviolet, on the spectra of several molecules of astronomical interest, and on miscellaneous laboratory instrumentations. Physical mechanisms of cometary physics have been discussed on the basis of new observational material. Remarks on various space experiments are expressed.

1. - INVESTIGATIONS BEING UNDERTAKEN.

Introduction. -

The research program as outlined in contract AF 61(052)-587 reads as follows :

"Experimental, observational and theoretical research will be carried out, as follows :

A. - Investigation of the vacuum ultraviolet spectra of atmospheric and extra-terrestrial molecules : with laboratory excitation sources including photoflash photolysis, short impulse sources, shock tubes and electronic beams.

B. - Investigation of geophysical and astrophysical processes in which the far ultraviolet (especially solar) radiation plays a role, including prediction of far ultraviolet auroral and cometary spectra.

C. - Surveys and theoretical investigations of processes in the vacuum ultra-violet and soft X-ray regions which will provide the basis for obtaining an optimum interpretation of results from space probes and satellites".

These topics A, B and C will be summarized as follows :

A. - Laboratory work.
B. - Geophysical and astrophysical processes.
C. - Investigations related to space experiments.

A. - LABORATORY WORK.

I. - Time Resolution of Spectra in the Far Ultra Violet.

Introduction.

The investigation of various mechanisms encountered in rarefied gases submitted to an excitation has increased in importance recently, owing to the possibility to carry out experimental researches in atmospheric layers at high altitudes. The theoretical studies on the proposed models, supported by static experimentation can however, in many cases, only suggest different possible mechanisms between which a decision is often difficult to reach. On the other hand investigations prompted by the study of thermonuclear reactions have resulted in a great headway in the investigation of the mechanisms which operate in plasmas at very high temperature. The time resolving spectroscopic methods which have been developed on this occasion find a direct application in the study of plasmas of lower energy and in the study of more or less ionized rarefied gases as found in many cold atmospheres.

It appears clearly, for the study of hot plasmas as well as for the study of rarefied atmospheres that the spectral region below 2000 A is of primary interest. If the technique is to be extended in the far ultra-violet it is obvious that only stroboscopic or electronic means offer the possibility to work in a vacuum. If the former allows photographic records with its implied advantages from the viewpoint of sensitivity and simultaneity, also present in the second method, the latter however proves to be more convenient, more flexible, more accurate and offers many possibilities for subsequent improvements. Under its simplest form, which consists of an oscilloscope display of the light pulses by means of a photo-multiplier tube, the electronic method has been used by numerous authors. The technique supplies a means for studying the shape of non-recurrent pulses. If the phenomenon is recurrent at a high frequency it becomes possible to improve the technique so as to increase the accuracy. Phelps has, in fact, developed a method based on sampling of a repeating light pulse, the observation aperture scanning slowly the entire pulse. Thus it becomes possible

to record an extremely fast phenomenon; the narrowness of the aperture enables then the greater part of the noise to be eliminated and brings out the details, which otherwise would go unnoticed on the screen of an oscilloscope. In the work of our laboratory the technique of time resolved spectra by sampling is extended to the far ultraviolet region and is used for the investigation of electrodeless discharges produced by high frequency pulses.

a. - Instrumentation.

The purpose of the method lies in the investigation of rapid mechanisms based on the spectroscopic identification of rapid molecules, atoms, radicals or ions taking part in the system. The time resolving apparatus is mounted on a spectrograph which is designed to operate at a pressure of 10^{-5} mm Hg. Mechanically very simple it has been built according to the Paschen design, i.e. it is made up of fundamentally stationary components : slit, grating and Rowland circle. The Rowland circle, or rather its materialization is of a fairly complex design and enables, in a small space, the apparatus to be used in the two conventional ways.

1) Photographic recording. A photographic frame equipped with an accurate mechanism allows up to 8 consecutive spectra to be recorded. Moreover a device enables the band under investigation to be separated from the reference spectrum.

2) Photo-electric cell recording. For this purpose, the photographic frame holder makes up a rollertrack on which travels a carriage bearing the slit and a 1P21 photomultiplier tube. An adjustment allows the slit to be located exactly on the Rowland circle.

The grating, used in the first order has 600 lines per mm and is grooved over an area 150 x 75 mm. Its radius is 3 meters. In front of the slit is mounted a pyrex tube through which the investigated gas circulates. The gas, obtained from a metallic pressure bottle is purified beforehand by passage through a liquid nitrogen trap (for N_2) or through a charcoal trap at liquid nitrogen temperature. It is excited at a frequency of 3300 MHz

by pulses of 0.5, 1 and 2 μ sec duration. The pulses with a peak power of 144 kW are generated by a radar pulser, type RT-31/APS-2F. The radiation is coupled to the gas tube by means of a wave guide built according to specifications given by F.P. Broida and M.W. Chapman. The primary pulses from a double pulse generator control the magnetron and therefore the high frequency pulses. For oscilloscope display the primary pulses are directed into the trigger input of the instrument. The secondary pulses which are time delayed with respect to the primary pulses by an amount adjustable between 0.2 microsecond and several microseconds, are fed to the control input of a gate circuit. The gate produces an output signal proportional to that received by the photomultiplier tube but only during the reception of the secondary pulse. It may easily be seen that by slowly changing the time delay the gate output pulses will reproduce the shape of the light pulse received by the photomultiplier tube : the signals are amplified selectively at the frequency of recurrence, rectified, then fed to a recording potentiometer. The time resolving power is limited, for the time being, by our double pulse generator, to 0.25 microseconds. The signal amplitude is inversely proportional to the desired resolving power. When the resolving power is small (long after-glow) the sensitivity may be large, since the observation time may be made to last one half the period of recurrence. For very intense lines photographs of the oscilloscope trace have proven to be of great usefulness. Preliminary results, to be considered below were obtained in this manner. However background noise is still great and limits considerably the number of lines for which the shape can be time-resolved.

The load resistance of the photomultiplier tube had to be reduced to 500 ohms in order to obtain a sufficiently small time constant; this does not reduce appreciably the amplitude of the pulses. Finally a transistorized impedance adapter is being worked on; it should allow the time constant to be reduced to a value below that which is attained presently (0.1 microsecond).

b. - Preliminary results.

We have undertaken a study of the excitation of helium for the obvious reason of the simplicity of the involved phenomena. The HeI-line examined was λ 3883.6. It appears clearly that the light pulses experience a large delay with respect to the high frequency excitation pulses. Furthermore, the intensity changes strongly with pressure. The well-known afterglow due to molecular helium is clearly visible. We shall however confine ourselves to the study of the leading edge of the light pulse shape corresponding to the line located at λ = 3888.6 A. The light pulse may be characterized schematically by two magnitudes, for which it is interesting to study the variations with respect to pressure. These are the maximum intensity and the delay with respect to the excitation. If the latter is easy to measure in absolute units (microseconds) the former will have to be measured in arbitrary units. The curve giving the maximum intensity as function of pressure may be divided into two regions : one below 1 mm and one above 5 mm, separated by a transition region (1-5 mm). Below 1 mm the intensity appears to be an increasing function of pressure. Above 5 mm the intensity decreases as an inverse law of pressure. The delay Δt is measured between the beginning of the excitation and the maximum of the light pulse. Above 1 mm Δt follows a hyperbolic law with respect to pressure.

c. - Conclusions.

The results reported here are only preliminary. They are intended to illustrate the value of the method. It appears in fact that the curves obtained are related in their essential aspects to physical values, independently of any instrumental parameter. The described apparatus is at present being improved in the light of these preliminary results. In particular work is being carried to increase the time resolving power and the accuracy of time measurements.

II. - Contributions to the Spectra of Various Molecules of Astronomical Interest (H_2, D_2, HD; C_3; SO_2^{16}, SO_2^{18}; H_2O ?).

a. - Absorption Spectra of H_2, D_2 and HD.

A new transition has been discovered and the vibrational analysis of the bands has been performed. The transition corresponds to $D'' \; 5p \; ^1\Pi_u - X \; ^1\Sigma_g^+$. A new term has thus been added to the n p Rydberg series. The vibrational constants have been computed for H_2, HD and D_2. They are collected in Table 1.

Table 1.

$D'' \; ^1\Pi_u$ (5p) state

cm^{-1}	H_2	HD	D_2
T_e	121 215.06	121 227.17	121 225.44
ω_e	2320.81	2011.90	1648.86
$\omega_e x_e$	64.68	49.34	32.68

Within the limits of the experimental errors these results agree with the isotopic rules. The quantum defect corresponding to the new state is -0.0794, which compares with the values -0.0807, -0.0805 and -0.0776 found for the C, D and D' states (2C, 3C and 4C). The deperturbation is now complete for the C states and is well under way for the B states (H_2, HD and D_2 molecules).

After completion of the study of the deperturbation of the C- and D-states a least square program has been prepared in order to secure the best constants. The origins and rotational constants have thus been computed. Some scattering appeared in the results obtained for the rotational constants. For this reason the latter have been recalculated by another method based on the second differences. The two methods seem to give entirely independent results. The best values have been singled out

and averaged.

A monograph on our work on the spectra of H_2, HD and D_2 is being prepared.

b. - Absorption Spectrum of C_3 and Comparison with Cometary and other Emission Spectra of the Same Molecule.

The new investigation of the absorption spectrum of C_3 which was started about one year ago has been continued with great vigor. First the rotational analysis of four bands ($\lambda\lambda$ 4050, 3914, 3905 and 4071) was repeated and accurate constants, including values of the Λ-doubling, were obtained.

The rotational structure of several other bands was then partly analyzed, and some clarification was brought in the general character of the whole spectrum.

However, in spite of the very high dispersion used to obtain the spectrograms under investigation, a complete analysis turned out to be impossible, and new spectrograms with the highest possible dispersion had to be secured.

Excellent spectrograms in a high order of the 35 foot-grating of the National Research Council in Ottawa are now at our disposal. The measurements of these spectrograms which started at the beginning of December have made considerable headway. The analysis of the bands is proceeding in a promising fashion.. Several interesting results will be presented at a meeting of the Faraday Society in Dundee, in April. A detailed report will be prepared as soon as possible.

c. - Spectra of SO_2^{16} and SO_2^{18}. -

While the SO_2-molecule may not be of direct geophysical or astrophysical importance it is of considerable interest in that it reveals information which may help greatly in the analysis of the spectra of other triatomic molecules which are of geophysical or astronomical interest.

A few results on the SO_2-spectrum have been obtained; they will be mentioned at the Dundee Meeting of the Faraday Society. We hope to obtain new high dispersion spectrograms during the Summer. A detailed report will be prepared as soon as possible.

d. - Peculiar Spectrum appearing in Water Vapor.

A. Michel (1957) has announced the presence of a previously unknown emission in the region λ 1700 - λ 1900 when a discharge is produced in a rapid flow of water vapor. The author mentioned that the emission could be excited in a high frequency discharge as well as in an iron hollow cathode. Exposures of several hours were required with a one meter-grating. As far as we could find out no further successful work on this emission has been carried. We have tried to determine the best excitation conditions in order to obtain spectrograms of this emission with our 3 meter-grating.

The attempts with Geissler-type discharges were not successful, but encouraging results were obtained with an aluminium hollow cathode. It seems that the emission is favored when the Lyman system of H_2 is absent. We are trying to determine the best excitation conditions.

III. - Miscellaneous Laboratory Instrumentations.

a. - Pulsed High Frequency Generator.

Since the 3 meter vacuum-spectrograph could not be devoted to this generator all the time we mounted the latter on a Hilger Medium Quartz Spectrograph. With this new instrumentation we have reconsidered every detail of the first installation. This has led us :

1. - to use for the discharge a quartz tube, which can be baked before the experiments;
2. - to improve the purification of the gases used in the discharge, particularly helium;
3. - to mount a recording system on the Hilger spectrograph, in order to permit an easy choice of the line or band to be studied.

The installation is now ready for the study of the line or band profiles with photographic recording of the oscilloscope traces.

In order to get better traces, the sampling system has been completed with an X-Y recorder. A device designed for giving a signal proportional to the delay, to be introduced as X-input, is in an advanced stage in our electronic workshop.

A satisfactory method of purification of helium has been adopted; the helium flows through active charcoal and is cooled by liquid nitrogen. Attempts at purifying argon have also been made with the help of active charcoal and cooling by dry ice first, liquid nitrogen next.

These gases have then been used with the radar-type generator.

b. - Hollow Cathode.

Experiments with a first hollow cathode have been conducted with nitrogen and hydrogen in order :

(1) to test the stability of the continuous discharge (in a stream of gas the discharge remains localized in the graphite cup in the range from 5 to 10 mm Hg);

(2) to check the favorable influence of an increase in temperature of the cup on the stability of the discharge;

(3) to examine the increase in courant as a function of temperature (for a constant voltage of the discharge).

With nitrogen the main spectra obtained are those of CN, N_2^+, N_2 and weak C_2.

With hydrogen we found CN and the Angström system of CO (this disappointing result is probably due to insufficient degassing after the experiments with nitrogen!).

On the basis of these results it was considered desirable to prepare a new source which could reach temperatures of the cup higher than 2000°C and work with pulse discharges. It was also necessary to insure proper streaming and purification of the gas (see section III a).

This new hollow cathode installation has been designed and its construction started; the same applies to the purification system.

In the mean time we used the old installation for a study of the discharges in a regime of pulses. The pulse-generator provides pulses of 0.8 microsecond-duration with a recurrence frequency of 1707 cycles; its maximum peak power is approximately 6 kilowatts. We also attempted to convert an existing source of continuous excitation into a source of high intensity-pulses. The involved electronic circuits are under investigation.

A series of experiments with pulse discharges have been carried with the old hollow cathode-installation. The discharge remains stable for a range of pressures of N_2 from 2 to 10 mm Hg. The frequency of the discharge varies from 1 KHz to 20 KHz. While the glow is weak and localized at the anode for 1 KHz its intensity brightens, and it begins to fill the inside of the cathode when the frequency increases. We next set the frequency at 20 KHz and studied the behavior of the discharge as a function of the temperature of the cathode. When the latter increases the glow has a tendency to get outside of the cathode, and its intensity decreases sharply. It should be remembered that in continuous operation the discharge which is not stable at normal temperature becomes confined to the interior of the cathode when the temperature of the latter increases.

The spectrum of the pulse discharge in air at normal temperature is mainly characterized in the region λ 3900 - λ 4700 by the N_2^+ emissions. The $\Delta v = -1$ sequence of CN is well developed; a few bands of the 2P system of N_2 are also present. In the red region there appear several bands of the $\Delta v = 4$ sequence of the 1P system of N_2. To obtain a similar spectrum in a continuous discharge the temperature of the cathode has to be raised to approximately 1000°C. The pulse discharge which was utilized in these experiments did not have its maximum power. Thus far unidentified band with triple heads appear in the region of the 1P system; they are degraded toward the red; they will be studied with higher resolution.

Of course these experiments will be systematically repeated with the new installation, and the spectra will be extended into the ultraviolet.

It is expected thatthe new hollow cathode will be in operation in the course of the Spring 1963. As soon as results become available we shall prepare a detailed report for OAR.

c. - Other Sources.

Guided (Feussner type)-discharge. - We have received the modulation unit of a radar SCR-584. With the corresponding HT unit we shall obtain pulses of 22 KV, 12 amps, with 0.8 μ sec duration and a frequency of 1707 Hz. The work is under way.

Weissler type-source. - This source has received the final modifications (mainly related to safety). It provides clean spectra, but no continuum. This is probably due to the low energy of the power supply.

The helium spectrum has been excited with this source, powered by a pulsed D.C. power supply, in order to obtain time resolved spectra. Preliminary results have been obtained with the rotating stroboscope (see section AI). The installation is working properly; the improvements in the results are gratifying.

Hinteregger type-source. - Everything is ready for the first trials. There will be conducted this year. Only problems of manpower have slowed down the work on these "other sources".

Photo-flash. - Plans are in preparation.

Intense source of Lyman α. - This source should eventually be used for the excitation of fluorescence by Lyman α. Preliminary work on a source appears promising.

d. - Other Instruments.

21 foot-vacuum spectrograph. - The drawings are progressing. The design of the main tank is finished, and the construction has begun.

The delay imposed by the factory may extend to March or April 1964. In the mean time we have undertaken the detailed drawings of the grating support.

<u>Photoelectric comparator.</u> - The measurements will be made by comparison of two traces on an oscilloscope. The detailed designing is under way. The required optical parts have been received. An experimental mounting of the optical system has been built and found satisfactory. The construction will begin soon.

<u>New micro-intensitometer.</u> - Considerable attention has been given to the problem of the new micro-intensitometer for reduction of laboratory and astronomical spectrograms. Two separate devices have to be combined in order to obtain the proper result :

(a) a microdensitometer, giving the optical density of the sample as a function of wavelength;

(b) a device which will transform this density into the intensity of the incident light, according to a calibration curve, itself variable with λ.

For apparatus (a), we have chosen a new Zeiss photometer, of type G II, which enables to record sample lengths up to 20 cm at a time, with 27 different ratios of speed between the sample and the strip-chart recorder. One single motor drives both the recorder and the sample, giving thus the best possible synchronization of the motions and the least distortion of the scale on the tracing.

As far as (b) is concerned, we have examined different systems such as high speed computer reduction with digitized voltmeter, the use of an array of electrical resistances, etc. Finally, we decided to use an X-Y Recorder, Model 2 DR by Moseley, using it not as a data plotter, but in combination with a curve follower unit, so that the input (density) will be transformed into the corresponding intensity, according to a calibration curve. We will use a photoelectric readout of the curve, allowing us to use untreated lines drawn on ordinary paper. Additional controls will permit the adjustment of the X scale to black-clear glass deviation, the control of the gain and of the zero.

The reduction procedure will thus be the following :

(1) density recording of the calibration marks at various wavelengths in order to draw the corresponding calibration curves;

(2) running of the sample with the desired speed ratio for each region of validity of the calibration and direct intensity recording of the tracing.

This installation should be in working order in the course of this year.

Vacuum ultraviolet-monochromator. - This instrument of the Czerny-Turner type will be available soon. It will be of great help for the work on pulsed light sources, and will be used jointly with the 3 meter-vacuum spectrometer.

B. - GEOPHYSICAL AND ASTROPHYSICAL PROCESSES.

Various investigations or plans on geophysical and astrophysical processes in which the far ultraviolet radiation plays a role or which are concerned with space vehicles are summarized in Section C on Space Experiments.

Work on comets has been continued. The discussion of the fluorescence mechanism for C_2 and NH_2 has been completed. A detailed description of the spectrum of 1957d has been made. Excellent spectrograms (many with high resolution) of Comets Seki-Lines (1962c), Honda (1962d), Humason (1961e) and Ikeya (1963a) have been obtained at Observatoire de Haute Provence. The essential results are:

Comet Seki-Lines (1962c). - Various emissions reveal detailed structures, some better resolved than ever before (f. ex. CN). The emission observed at λ 6300.97 A (without radial velocity correction) cannot be assigned to terrestrial [OI]. After radial velocity correction the wavelength becomes λ 6300.30, which coincides exactly with cometary [OI]. The continuum is of average intensity.

Comet Honda (1962d). - Weak continuum; the spectrum is normal.

Comet Humason (1961e). - Large heliocentric distance ($r \backsim 2.5$ A.U.). Has a very unusual spectrum consisting of strong CO^+ and N_2^+, weak CO_2^+, CN and C_3. The tail emissions which are stronger than in any other comet extend into the central regions of the comet, within a few seconds of arc from the nucleus. The normal head spectrum is extremely weak. We have to deal with a very anomalous case (weak photodissociation of parent molecules into radicals; very strong ionization of stable CO and N_2 molecules, probably by collisions with solar particles).

Comet Ikeya (1963a). - No continuum. - Excellent structure of C_3 (best ever obtained), also of CH. Presence of isotopic bands $C^{12}C^{13}$ and $C^{13}C^{13}$. The spectrum of C_3 will be fruitfully compared with the laboratory spectrum, as soon as the analysis of the latter is completed.

The discussion of the behavior of [OI] in comets has been completed and published. It acquires importance, as evidenced by the investigations by Dr. Biermann. The forbidden lines of [OI] are present in many cometary spectra. Sometimes the auroral transition λ 5577 is strongest, sometimes the nebular transition λ 6300 - λ 6364. We have examined the behavior of [OI] in many comets. It has been found impossible to find any convincing correlation between solar phenomena (bright solar flares, relative sunspot number), terrestrial phenomena (geomagnetic indices, aurorae) and the occurrence or intensity variations of oxygen forbidden lines in the examined cometary spectra. The relative intensities of nebular transitions (red doublet) or auroral transitions (green line) of oxygen have been calculated on the basis of two different mechanisms : fluorescence and electron collisions. In the case of pure resonance the red doublet is the only possible emission. The excitation by electron collisions implies that the red lines should always be more intense than the green line in the range :

$$10^3\ K \leq T_e \leq 10^5\ K\ ;\ 10^3\ el.cm^{-3} \leq n_e \leq 10^5\ el.cm^{-3}.$$

The intensity ratio is a slowly varying function of the electron density n_e. It is smaller than 10 if T_e is higher than 5.10^4 °K. Excitation by collisions with protons is likely to be negligible. The possible contributions of recombination processes like

$$O_2^+ + e^- \longrightarrow O^* + O^{**}$$

and of photodissociation mechanisms remain to be taken into account : this is being studied in Dr. Biermann's group.

The details of the high resolution profiles of CN(0-0) obtained at OHP (especially of Seki-Lines, 1962c) cannot all be interpreted on the basis of the Utrecht Microphotometric Atlas of the Solar Spectrum. We have obtained better recordings of the solar spectrum near CN(0-0) with the Jungfraujoch spectrometer of Prof. Migeotte. The calculation of the synthetic cometary profiles by the usual method is under way. Simultaneously Carrington's new method is being applied. At the present time a system of 40 equations has been established; we hope that it will soon be solved on our ordinator.

One hundred copies of a Technical Note No. 1 entitled "Mie Scattering Functions for Spherical Particles of Refractive Index m = 1.25" have been shipped to the OAR Office in Brussels. The following considerations may be added.

Intensity functions and polarization degrees have been calculated for $m = 1.25$, $\theta = 90°$, $f(x) \propto x^{\alpha}$, with $\alpha = -4(1)2$ and also a gaussian distribution. The distributions x^{α} with $\alpha > 0$ do not give sufficiently uniform degrees of polarization in the range λ 4300 to λ 5900 (diameters varying from 10^{-4} to 10^{-6} cm); moreover these polarizations are negative. The calculations have then been pursued for $m = 1.25$, $\theta = 70°$, 80°, 100°, 110°, 120°, 130° and 140° with the other 6 types of distribution. For these same distributions we have computed i_1, i_2 and Γ for $\theta = 90°$, $m = 1.47$ and $m = 1.50$. As far as polarization degrees are concerned the exponential- and x^{-4} distribution functions fit best with the observations; it also seems that m should lie between 1.35 and 1.40.

Calculations of i_1, i_2 and ρ for $\theta = 90°(10°)140°$ have been made for the exponential and x^{-4} distributions. The comparison with the observations is in progress; it will be reported soon.

The paper on cometary outbursts by Ch. Whitney (Ap. J., 122, 190, 1955) has been discussed on the assumption that the increase in brightness is due to scattering by small solid particles which have been ejected from the nucleus. Assuming resp. m = 1.25 and 1.50 and radii of 10^{-3}, 10^{-4} and 10^{-5}, the ejected masses - for densities 0.81, 0.91 and 1.62 gr/cm^3 - turn out to lie in the range 10^8 to 10^{13} grams for the cometary outbursts considered by Whitney (Swift, June 4, 1899; Holmes, Jan. 16, 1893; Pons-Brooks, Sept. 23, 1883 and Jan. 1, 1884). Assuming velocities of ejection of 0.2, 0.8 and 1.6 Km/sec, the kinetic energies of the halos turn out to be 10^{17} to 10^{23} ergs. A cometary nucleus of 1 Km radius requires a time 10^{-2} to 10^4 hours to absorb an amount of solar energy equal to the computed kinetic energies. Probably the absorption is localized and requires a longer time.

The scattering by cometary particles of carbon or iron will be examined as soon as the data at present in preparation by Dr. Donn at Goddard Space Flight Center (NASA) become available.

One hundred copies of a Technical Note No. 2 entitled "Scattering by Cometary Particles" will be shipped to the OAR Office in Brussels as soon as the reprints are received from the printer. This is actually a report presented at the Interdisciplinary Conference on Electromagnetic Scattering at Clarkson College, Potsdam, N.Y., last August.

The photometric observations of 1960 i (Encke) have been completely reduced and discussed. They were made with the same kind of instrumentation as at the previous (1957) passage of Encke's comet. There seems to have been a decrease of the absolute intensity of the CN-emission in 1961 (January), compared with 1957. It is very desirable to repeat similar observations at a future passage (The 1964 passage will not be favorable in the Northern-hemisphere).

Fifty photographs of Comet Humason (1961e) have been obtained with the Schmidt camera of OHP. They will be investigated and the behavior of this peculiar object will be compared with that of more normal objects such as Burnham (1959k) and Seki-Lines (1962c). On certain nights sequences of several pictures of 1961e have been obtained. They give the possibility of discussing the enormous variations of aspect of the tail. These variations are sometimes conspicuous even in the course of a single night. They will be studied in relation to solar activity.

The study of the behavior of the tail of Comet Burnham (1959k) is finished; a report is being prepared.

A new line of cometary investigation has been initiated. We examine the possibility of occultations of radio-stars by cometary heads or tails. Comet Humason (1961 e) was examined for this possibility until June 1963 : no occultation will take place. On the other hand several occultations may take place in the case of Comet Encke 1964.

Actually we have also examined the possibilities of occultation by Comet Ikeya, but without success.

A model of "cometary electronic atmosphere" is being studied theoretically. This involves the origin of the cometary electrons and the nature on the forces in action.

We hope that observations of occultations of cosmic radio-sources by comets will be attempted some time in the near future.

C. - INVESTIGATIONS RELATED TO SPACE EXPERIMENTS.

a. - The Lyman Lines in Stellar Spectra.

Work is in progress on the programming of the profiles of the absorption coefficient for Lyman-lines in B- and A-stars. Changes had to be recently introduced in order to correct an erroneous normalization method given by H. Griem in his theory of the broadening of hydrogen lines. This work will be of help once far ultraviolet stellar spectra are obtained with orbiting telescopes.

As a preparation for the work on the Lyman lines a theoretical study has been made of the variations of the profiles of the Balmer lines in A-stars, as a function of surface gravity; the calculated results have been compared to the observations.

On the other hand a study of the absorption coefficient of the H_2 quasi-molecule is under way. Erkovich has computed this coefficient for temperatures in the 2000-6000° range. Certain values appeared doubtful, but a careful study made here showed that these disputed values were due to typographical errors. The work is now being extended to higher temperatures : 10,000 to 25,000°, in order to find out if the absorption by H_2 may contribute to the ultraviolet absorption in hot stars.

b. - Profile of Lyman β in the Solar Spectrum.

The computation of the solar Ly β line profile is progressing satisfactorily. Improvements have been made to a previous calculation by Morton and Widing who used erroneous values of the zeros of the fifth order Hermite polynomials.

The profile of solar Ly β will be used in a study of the possible fluorescence effects with the λ 1025 OI transition in interplanetary space.

c. - Far Ultraviolet Color Indices of Hot Stars.

We are studying the feasibility of a satellite experiment in order to determine ultraviolet color indices. Attention has been given to the choice of the filters and to the possible number of observable objects with a 30 cm-telescope. This number depends critically on the noise of the photomultiplier. If the dark current can be kept as low as 10^{-14} amp. one should be able to observe about 25,000 stars, mainly of types B and A, in three different wavelength intervals. Our laboratory work on this project - at least in the near future - will mainly consist of the detailed study of the photoelectric devices and of the reflecting surfaces and filters. Actually this work should start around June, i.e. as soon as the monochromator becomes available.

d. - Far Ultraviolet Spectra of Aurorae.

Theoretical predictions had already been made on the previous contract. The stratification and absorption effects on the far ultraviolet spectra of aurorae have been studied, but more work is still required and is under way.

We are planning a rocket experiment in which a luminous spectrograph would be launched through an aurora, and the integrated spectrum recorded photographically in the range 1000 - 3000 A. To this effect we have designed an off-plane modified Wadsworth-type mounting. The optical parts are ready for testing the optical qualities of this mounting in the laboratory.

e. - Comet Probe.

A great deal of thought is being devoted to the necessary instrumentation of a possible comet probe. In preparation to such a project a comparative study has been started on the physical characteristics of the periodic comets. A report on this matter will be issued in the course of this year or early next year.

f. - Artificial Comets.

The behavior of important cometary molecules in the field of solar radiation is being carefully reconsidered, in preparation for a projected release of NH_3 at a high altitude. Theoretical work is being carried on the mechanism of fluorescence of ammonia in the field of solar radiation, including the preparation of a synthetic spectrum of the fluorescent emission. Various laboratory tests are in progress, as well as investigations on the most adequate methods of release. It looks as if a first experiment may take place next Fall or Winter from a launching range in Sardinia : 40 kilograms of ammonia would be released at twilight at a height of about 240 kilometers.

g. - West Ford Project.

We have shown that over a period of several years there would be sufficient collisions of micrometeorites with the needles of a project such as West Ford to break them, hence the particles would become smaller, but more numerous.

A technical note on this matter is ready to be mimeographed and will be shipped in the near future.

h. - Observation of French Rockets.

In order to gain some experience in the field of experiments with sounding rockets two members of our team spent a week with Professor Blamont and his group in Colomb Béchar (Sahara). Two other members of our team spent a week at the Observatoire de Haute Provence with Professor Blamont's collaborators, at the time of the launching of sodium and potassium clouds from the Iles du Levant; they took part in the observations of the clouds.

i. - Theoretical Considerations on the Van Allen Belts.

The discussion of the conditions which limit the application of Alfvén's theory to the motion of a charged particle in a magnetic field yields a well defined criterion on the basis of experimental data as well as of observational data on the Van Allen belts.

This criterion allows one to construct diagrams giving, as a function of the energy of various types of particles, the maximum distance at which they remain trapped in the geomagnetic field.

Furthermore, taking this condition into account it is shown that, at large distances, the drift velocity and the corresponding induced current, should vary as

$$1/r_e^2 \quad \text{and} \quad n(r_e)r_e^2$$

respectively, where r_e is the distance to the center of the earth (at the

intersection of the equatorial plane) and $n(r_e)$ the number of particles of a given kind per cm^3 at distance r_e.

A technical note on this matter is ready for translation into English.

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2. - FUTURE PLANS.

The work on all three topics of the project will continue in a systematic way. It is expected that the far ultraviolet spectroscopic investigations and the preparation of space experiments will progress at an increasingly rapid pace.

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3. - PERSONNEL and ADMINISTRATION.

The work is proceeding according to the terms of the contract.

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